RBW FILTER SWITCH BOARD FOR THE MSA

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5/30/10 (modified 9/9/10)

The filter switch board for the MSA was built and tested. The purpose of the board is to select one of four filters for the final IF (aka IF2), to determine the resolution bandwidth (RBW) of the scan. The schematic of the board is shown in the Appendix.

The board contains two ADG704 one-of-four (SP4T) switches. The first one directs the IF2 signal to the input of the desired filter. The second one routes the output of that same filter to the board output. At any one time one filter (or "path") is selected and three are unselected. The selection is made by setting address lines A0 and A1.

Isolation

We are first concerned with the isolation of the switch board. That is, to what extent is there leakage through paths other than the selected one. When we select a narrow filter, we want to minimize the leakage through unselected wider filters, which would partially defeat the narrowness of the selected filter.

Figure 1 shows a model of the switch board, in which Path 1 is selected and we want to examine leakage through unselected Path 3.

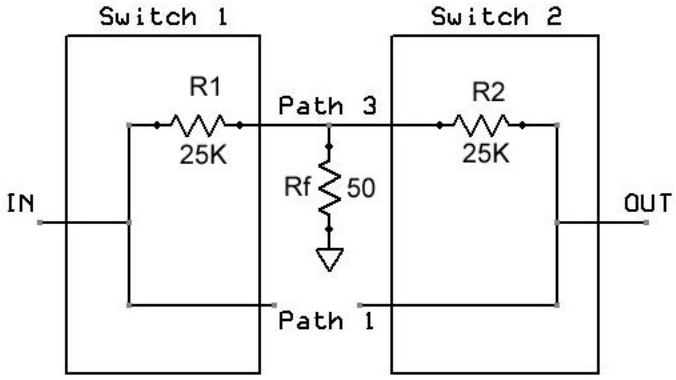


Figure 1—Model of dual switches

The filter inserted in path 1 is effectively connected to the board input and output (we ignore internal switch resistance in the "on" state). Path 3 is not selected, and is effectively connected to the board input and output through 25 kohm resistors. For testing, the "filter" in path 3 is a direct coax connection, though for a more realistic modeling of a filter, some impedance to ground must be added, and is shown as Rf.

Note that with Rf=50, any leakage signal through path 3 is attenuated by 54 dB by the voltage divider formed by R1 and Rf, and by another 54 dB by the voltage divider formed by R2 and the 50-ohm impedance of the board's load, for a total attenuation of 108 dB. If Rf is not present, there would be a single stage of attenuation created by combined R1+R2 and the board's load, which would amount to about 60 dB, which is only 6 dB better than would be obtained with a

single switch. Therefore, in order to get full benefit of the isolation of both switches, it is necessary to have impedance Rf in place. More on that later.

Several transmission tests were performed by attaching the TG to the board input and the MSA input to the board output. Path 1 was selected but no filter was inserted in path 1. Rather, the path 1 connector from switch 1 was terminated in 50 ohms. The path 3 connector from switch 1 was connected to the path 3 connector for switch 2 in a variety of ways. No connections were made to paths 2 or 4. The filter switch board contained no shielding, so it is possible that some small improvement in isolation would be obtained when the board is fully shielded—in particular, there is provision for a fence between switches 1 and 2.

Figure 2 shows the test with path 3 consisting of a coax tee with 50 ohms attached to the third leg. This matches the schematic of Figure 1.

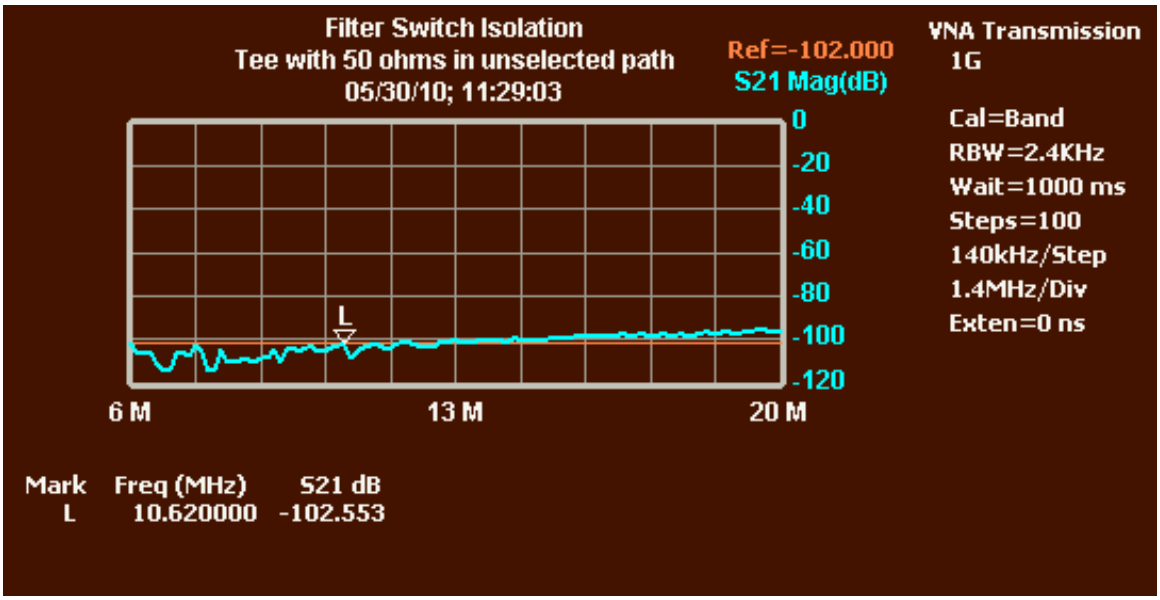


Figure 2—Path 3 is coax tee with 50 ohms on third arm

In the area of 10.7 MHz, the leakage in Figure 2 is about -102 dBc. We show the leakage over a broad frequency range, but we only care about leakage in the area of IF2, which is always in the neighborhood of 10.7 MHz.

The leakage level shown in Figure 2 at 10.7 MHz means that, no matter how effective the filter inserted in path 1, a scan in spectrum analyzer mode of a -10 dBm signal would show a signal of at least -112 dBm, because that amount of signal will leak around the path 1 filter. That is not a significant problem, since signals of -112 dBm are likely to be lost in the noise anyway, unless you are looking very carefully with a very narrow resolution filter and very strong video filtering.

To show the effect of Rf in Figure 1, the test was repeated with path 3 consisting of a direct coax connection, with no Rf. The results are shown in Figure 3.

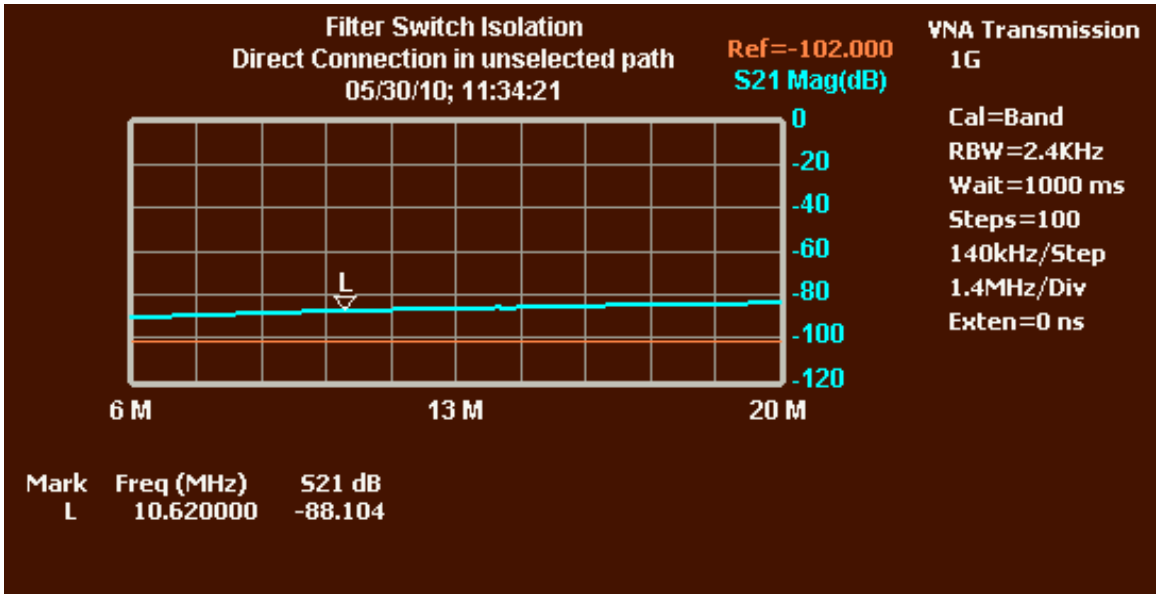


Figure 3—Path 3 is direct connection

The orange reference line in Figure 3 marks the level of marker L from Figure 2, to illustrate how the isolation has worsened with the removal of Rf. Note that even without an explicit Rf, the switch capacitances at the path 3 connections will cause an effective Rf that is well below infinity. Therefore, the difference between having and not having Rf=50 ohms is about 15 dB, somewhat less than you would think from theoretical analysis of Figure 1.

The isolation in Figure 3 is not bad, but we would certainly prefer to be closer to Figure 2 if possible. This means we would like unselected filters to present an impedance to ground as low as possible, especially within their normal pass bands. Actually, we do not have this concern with the narrowest filter, since leakage through that filter would be swamped by direct transmission through the selected filter (assuming all filters have the same center frequency).

Next, we placed an actual filter in path 3. It was a simple LC bandpass filter with very broad bandwidth. The results are shown in Figure 4.

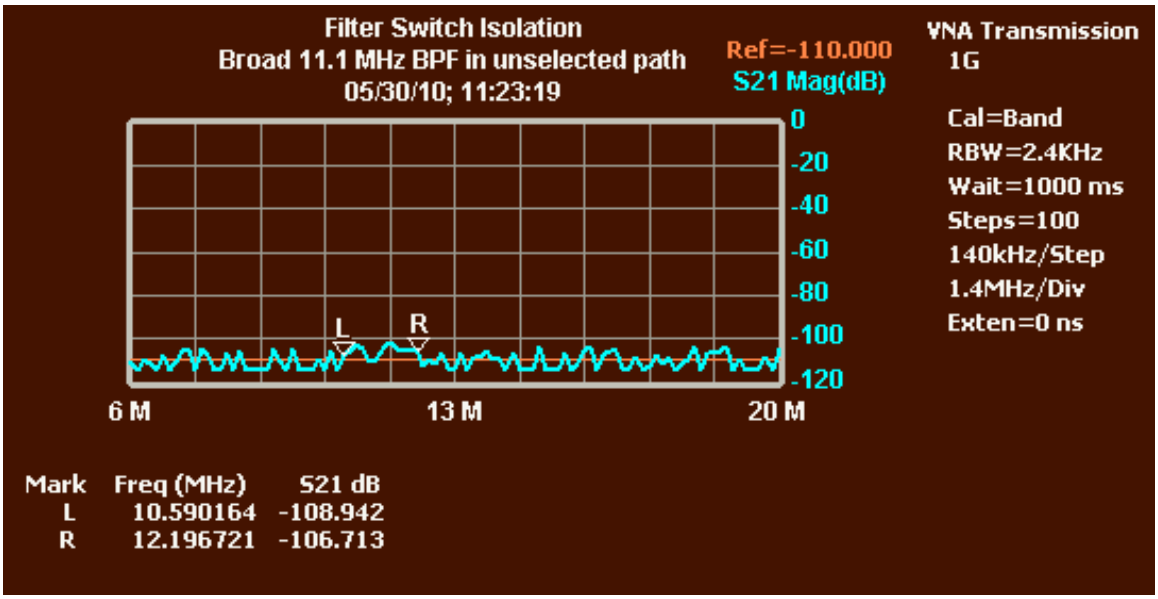


Figure 4-Band pass filter in path 3

The orange reference line at -110 dB is approximately the noise floor. The leakage through the band pass filter can just barely be seen between markers L and R, which is the filter's pass band. Inside that pass band, the filter impedance is roughly 50 ohms and we get results close to those of Figure 2. Outside that pass band, the filter presents a very low impedance to ground (i.e. Rf is very low), so leakage through path 3 is negligible.

Keeping Rf Low

As has been shown, best isolation is obtained when unselected filters present a fairly low Rf, especially within their normal pass band. In general, we can expect that filters will meet this requirement, even though an unselected filter is terminated only with the capacitance of switch 2. LC filters such as that of Figure 4 will almost always have low Rf. Crystal filters with matching components (LC or transformer) on their inputs and outputs will generally have low Rf because (1) the input matching components would do so even if directly terminated in high impedance and (2) the output matching components will present only a modest terminating impedance to the actual crystal filter, even though terminated in high impedance.

In the event a filter is encountered that presents high Rf within its pass band when not terminated, the leakage would look more like Figure 3 than like Figure 2. This would only be an issue for relatively wide band filters, because leakage is an issue only if it is outside the pass band of the selected filter. The leakage could be reduced by adding a shunt 100 ohm resistor at the filter input, followed by a series 18 ohm resistor leading to the filter. This keeps Rf low and still presents 50 ohms to the filter, at the cost of slightly increased insertion loss.

Insertion Loss

Finally, we want to be sure the insertion loss of the filter board is not excessive. Figure 5 shows the loss to be below 1 dB in the area of 10.7 MHz:

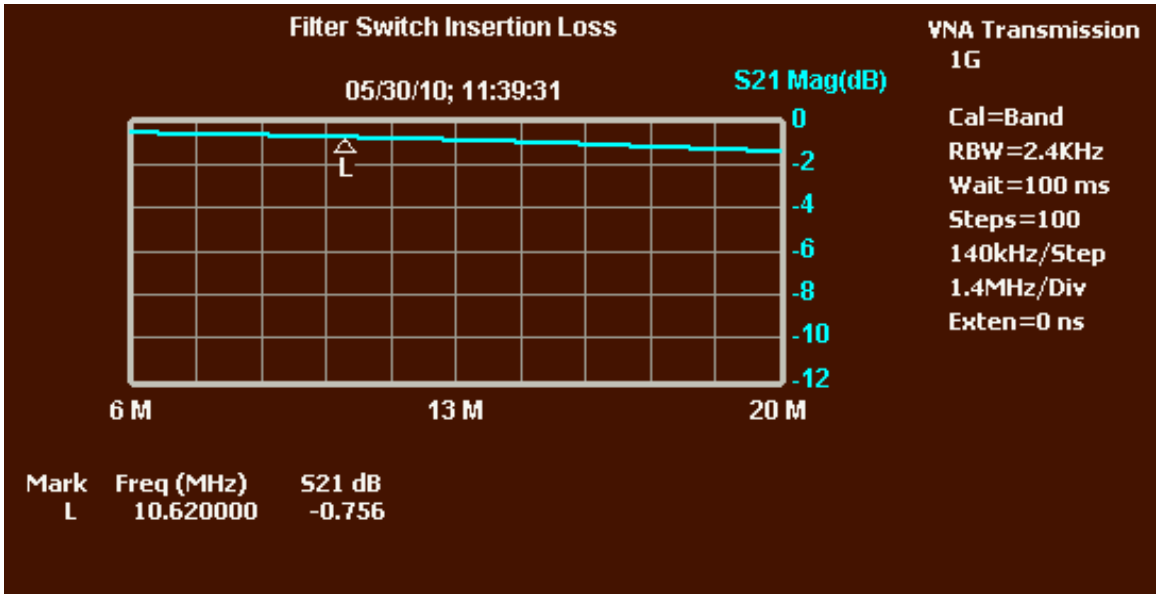
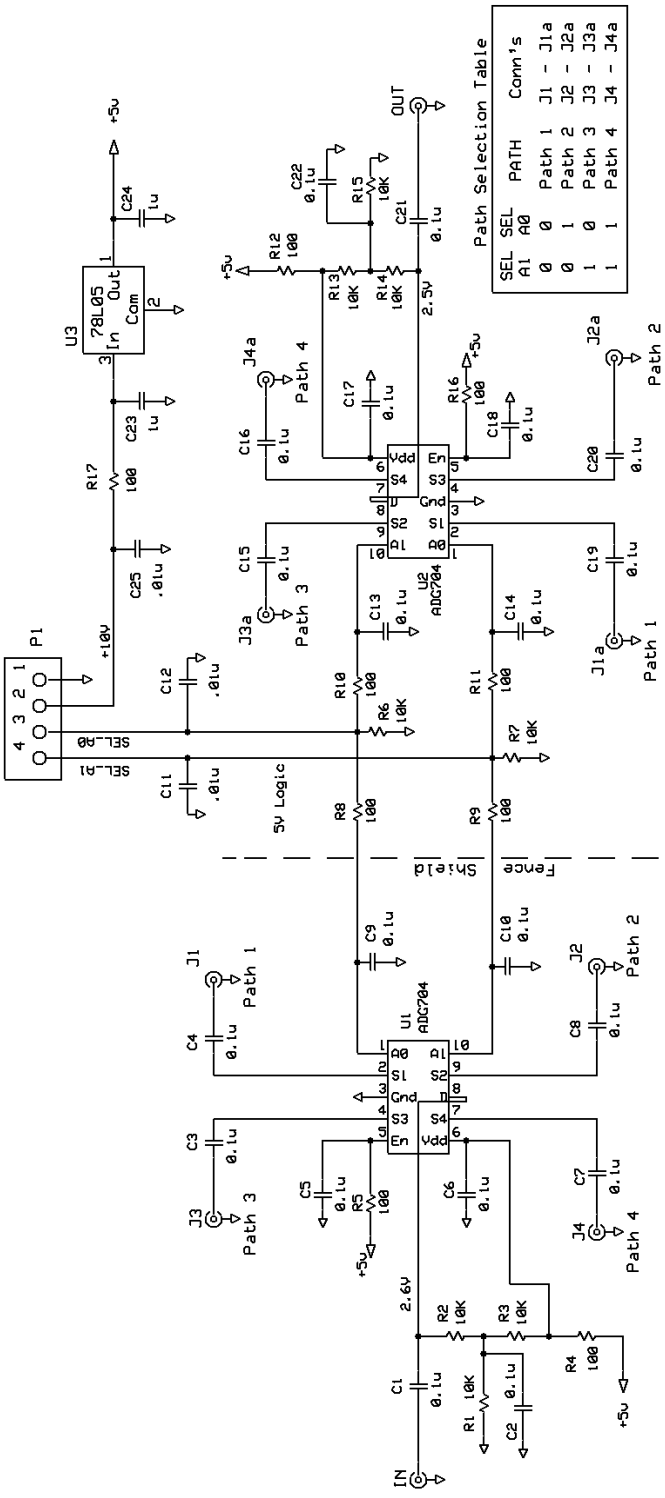


Figure 5—Insertion loss

Figure 5 was generated by using a direct connection in path 3, and selecting that path. The loss is only 0.75 dB, which is negligible.

APPENDIX—Schematic



Note: A 3.9 uH inductor, shunted to ground, can be added at input and output to neutralize the switch capacitance in the 10-11 MHz range, but may not be necessary.